APPLICATION AND USE OF BRIDGED TAP ISOLATORS (BTI) FOR SUBSCRIBER LOOPS

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1. GENERAL

1.1 This section provides REA borrowers, consulting engineers, contractors and other interested parties with technical information for use in the design and construction of REA borrowers' telephone systems. It discusses in particular how Bridged Tap Isolator devices are used in subscriber loop applications.

1.2 Where the subscriber distribution in a loop may indicate the need of an end section (including bridged taps) in excess of 12 Kf, in many instances the transmission can be improved by the use of Bridged Tap Isolator devices hereafter abbreviated at BTI. Several techniques of achieving tap isolations are being explored but at present the only device considered satisfactory is the "Saturable Reactor" type or coil isolator. When the saturable reactor is used in this application, it is referred to as a Bridged Tap Isolator or BTI. These devices are also known by other names in the industry such as "inductor," "reactor," "bridge lifter," and "isolator."

1.3 BTI's are utilized to eliminate the effect of bridged taps so that subscriber line fills will not be adversely affected. When properly applied they electrically isolate taps and thus effectively contribute to reducing the end section after the last loading point to a maximum of 12 KF for any subscriber, even though the total physical length of the end section including taps may greatly exceed 12 KF. Also, used in central office locations for bridging pairs at the mainframe, they help improve line fills. The correct application procedures for using these devices are given in paragraphs 3 and 4.

2. PRINCIPLE OF OPERATION AND OTHER CHARACTERISTICS

2.1 The function of a BTI is to simulate the "on" and "off" switch action. The device has a pair of balanced windings like a loading coil through which d-c current can pass but where passage of speech frequencies depends entirely on the particular "state" of the switch. It is the presence or the absence of d-c loop current through the BTI which enables the device to produce "on" or "off" switch action. When there is no d-c loop current flowing through the BTI, as for example when the telephone set is on-hook, the device presents a very high impedance (switch in "off" position) ~~which adds to the~~ normal impedance of the line resulting in low bridging loss. Thus, when a BTI is placed at the beginning of a bridged tap under an off-hook condition the core becomes saturated, its impedance is reduced to a very low value, and the circuit through the tap then operates much the same as though the device was not present. The impedance characteristic of the BTI is shown in Figure 1.

2.2 The BTI requires that the d-c loop current remain above a certain minimum value in order to produce proper switch action. Insufficient current does not saturate the BTI and this can result in severe speech distortion or failure of the device to operate. BTI's may not be effective as bridged tap lifters when subscribers on the same line are located in different branches and more than one telephone set is off-hook at the same time. This is because the d-c loop current divides among the branches having sets off-hook and the individual branch current may not be sufficient to completely saturate its associated BTI. Inadequate core saturation can also result in loaded loops during revertive call conditions if subscribers have been placed between loading coils isolated with BTI's. This situation will also result in either severe speech distortion or inability of the subscriber to be heard. The amount of d-c loop current needed to properly operate BTI's is 23 milliamperes or more when the most distant telephone set is off-hook and 12 milliamperes or more in any branch when two or more telephone sets are off-hook at the same time. Failure to meet these requirements will result in severe noise or distortion problems. Correct procedures for maintaining adequate d-c loop current needed to assure proper operation are discussed in paragraphs 3 and 4 below. The insertion loss characteristics of the BTI with loop current are shown in Figure 2 at three different frequencies.

2.3 BTI's pass multifrequency ringing currents and dialing currents with almost negligible distortion. They also have the capability of working on lines which use tubes of the biased or unbiased types in series with ringers such as might be required for superimposed ringing. The insertion loss introduced into the loop by each BTI unit is approximately 0.3 db in the voice frequency range when the device is saturated. The total d-c loop resistance of the device is approximately 20 ohms which adds to the outside plant resistance. BTI's are quite susceptible to the induced voltage from power line exposure and excessive noise conditions can result if they are improperly applied. Paragraphs 3.7 and 4.10 give the correct application procedures which help avoid noise problems. BTI's cannot be used on lines using local battery talking or Western Electric Company 507 type telephone sets due to insufficient d-c loop current (less than 23 milliamperes). The elimination of the local battery from the telephone and the use of a 24-volt or a 48-volt booster power supply at the central office provides an adequate supply of loop current so that BTI's can be used. When using Western Electric Company 500 E/F monitor type telephone sets, or equivalent, the monitor feature becomes ineffective when used behind a bridged tap isolator because the high impedance of this device when not saturated will prevent passage of voice frequency currents. The same will also be true on loops which do not normally depend on d-c loop current for their operation such as program circuits, for example. With regard to testing subscriber loops, bridged tap isolators should be inserted on the subscriber side of branches or taps, generally as close to the bridging point as possible. When placed on the common side of the line at branch points they serve no useful purpose. Similarly when installed close to the telephone set they are not effective as bridge lifters. No more than two bridged tap isolators must be in series with the loop in a call between any subscribers in the loop.

2.4 A special type of BTI is available which uses a resistor connected across each of the windings in the BTI. The purpose of the resistors is to allow for ringers to still remain connected divided-to-ground. This arrangement, however, causes noise and where the influence from power lines is high, the amount of noise will be excessive even with high impedance ringers. Because this resistor type of BTI is still highly susceptible to noise and because it further increases the circuit insertion loss, its use is not recommended. The conventional (non-resistor type) BTI should be used and all ringers in the loop should be connected bridged.

2.5 Bridged tap isolator units are similar in size and appearance to an exchange type loading coil and can be similarly mounted in terminal housings. To avoid confusion with loading coils, the completed units are encapsulated in a bright red case. The unit bears the designation BG-40.

3. APPLICATION OF BRIDGED TAP ISOLATORS FOR CENTRAL OFFICE BRIDGING

3.1 Individual non-loaded pairs to be bridged at the central office must meet the bridged tap requirements of 9 KF maximum and individual loaded pairs to be bridged at the central office must meet the end-section requirement of 12 KF maximum.

3.2 Bridge up to three separate pairs only, each pair having not more than one subscriber, and place an office mounted bridged tap isolator in each pair. Use Table I to check that sufficient loop current will be available to the bridged tap isolators.

3.3 Bridge up to two separate pairs only, each pair having not more than two subscribers each and no bridged tap isolators on their field side. Place office mounted bridged tap isolators in each pair. Use Table I to check that sufficient loop current will be available to the bridged tap isolators.

3.4 Bridge up to two separate pairs only, one having not more than one subscriber and the other pair not more than three subscribers and no bridged tap isolators on the field side. Place office mounted bridged tap isolators in each pair. Use Table I to check that sufficient loop current will be available to the bridged tap isolators.

3.5 Do not bridge pairs at the central office which use bridged tap isolators on their field side.

3.6 Do not bridge pairs at the central office which are equipped with long line adapters.

3.7 Connect all ringers on a bridged basis only in the pairs being bridged at the central office using BTI's.

4. APPLICATION OF BRIDGED TAP ISOLATORS TO LOADED LOOPS

4.1 Connect those subscribers who are close together on the same line. Eliminate cable branches, laterals and taps not in use by cutting dead and leaving floating at both ends.

4.2 Connect subscribers beyond last loading point only. If the end section (total length of non-loaded main line and taps) is less than 12 KF with regard to any subscriber in the loop, do not use BTI's. If the end section with regard to any subscriber is longer than 12 KF, use BTI's to reduce this amount to less than 12 KF.

4.3 Do not connect subscribers between loading points and do not use BTI's to connect subscribers between loading points.

4.4 If the end section of 12 KF cannot be met with BTI's, use the 19-gauge low capacitance single-pair wire, only in the amount needed. A 24 KF end section using the low capacitance wire is equivalent to bridging 12 KF of exchange type cable.

4.5 If the end section is longer than 24 KF when using the low capacitance wire, a separate cable circuit must be extended.

4.6 Do not place BTI's in more than three different taps in any one loop.

4.7 Insert BTI's at tap bridging point only. BTI's placed close to the telephone set are not effective.

4.8 Do not bridge at the central office loaded pairs on long line adapters or loaded pairs using bridged tap isolators on their field side (after the last loading point).

4.9 Use the 24-volt or the 48-volt booster power supply on all loops having a loop resistance of 1700 ohms and greater to assure proper BTI performance.

4.10 NOTE CAREFULLY: Bridge all ringers in the loop where BTI's are used.

4.11 Where computations are required, use 0.3 db for the insertion loss of each BTI in a talking connection. REA TE & CM-426 shows typical examples.

4.12 The application of BTI's is not simple and straightforward but rather it is difficult and complex because of the inherent characteristics of the device. Therefore, to the extent possible BTI's should be eliminated from use by better subscriber grouping, cutting dead pairs not in use, etc. Good design should be the primary objective. Furthermore, problems with BTI's can arise at a later date if the subscriber loop has undergone physical change. Whenever problems are experienced with BTI's on revertive calls due to insufficient d-c loop current in one of the taps and it is not possible to provide other corrective means, the insertion of a balanced resistor of the correct value to make the current in the taps more nearly equal will be found helpful in solving the problem.

4.13 A more effective means for solving such a low loop current problem is to increase the voltage of the booster power supply in the central office. A 48-volt to 48-volt d-c to d-c converter can be used for doing this economically because it applies to a number of loops. This cost of such a converter unit for three ampere output capacity is approximately $300 and this cost is divided by all lines equipped with long line adapter equipment. In addition to improving BTI operation the increased voltage aids signaling as well as the transmission performance of the transmitter in the telephone set.

4.14 Excessive noise can be caused when BTI's are installed on subscriber loops equipped with automatic number identification of the type which inherently unbalances the line in the talking condition when the influence from the power system is present.

4.15 With certain types of central office equipment, one side of the line relay is heavily unbalanced. When BTI's are applied to such equipment, this will result in generation of BTI noise which may interfere as crosstalk to other working pairs. Furthermore, with some types of central office equipment, ringback tone distortion may be encountered on lines equipped with BTI's.

TABLE I

RESISTANCE GUIDE FOR BRIDGING PAIRS
AT CENTRAL OFFICE[1] MAIN FRAME

WHEN THE D.C. LOOP RESISTANCE[2] IN OHMS OF THE PAIR UPON WHICH THE OTHER PAIRS WILL BE BRIDGED IS:	THE D.C. LOOP RESISTANCE[2] IN OHMS OF THE PAIRS TO BE BRIDGED SHOULD NOT BE LESS THAN THE RESISTANCE OF COLUMN (1) AND SHOULD NOT EXCEED:
0-20	160
20-40	180
40-60	210
60-80	260
80-100	340
100-125	400
125-150	430
150-175	490
175-200	530
200-225	580
250	640
300	700
350	750
400	800
450	840
500	880
550	910
600	925
600-1000	1000

1 BRIDGE PAIRS ONLY WHICH MEET THE REQUIREMENTS OF PARAGRAPHS 3.2, 3.3 and 3.4. THESE PARAGRAPHS ARE REPEATED HERE FOR CONVENIENCE:

3.2 BRIDGE UP TO THREE SEPARATE PAIRS ONLY, EACH PAIR HAVING NOT MORE THAN ONE SUBSCRIBER, AND PLACE AN OFFICE MOUNTED BRIDGED TAP ISOLATOR IN EACH PAIR.

3.3 BRIDGE UP TO TWO SEPARATE PAIRS ONLY, EACH PAIR HAVING NOT MORE THAN TWO SUBSCRIBERS EACH AND NO BRIDGED TAP ISOLATORS ON THEIR FIELD SIDE. PLACE OFFICE MOUNTED BRIDGED TAP ISOLATORS IN EACH PAIR.

3.4 BRIDGE UP TO TWO SEPARATE PAIRS ONLY, ONE PAIR HAVING NOT MORE THAN ONE SUBSCRIBER AND THE OTHER PAIR NOT MORE THAN THREE SUBSCRIBERS AND NO BRIDGED TAP ISOLATORS ON THE FIELD SIDE. PLACE OFFICE MOUNTED BRIDGED TAP ISOLATORS IN EACH PAIR.

2 INCLUDE RESISTANCE OF PLANT ONLY AND LOADING COIL WHERE USED. DO NOT INCLUDE TELEPHONE SET RESISTANCE OR CENTRAL OFFICE EQUIPMENT RESISTANCE.

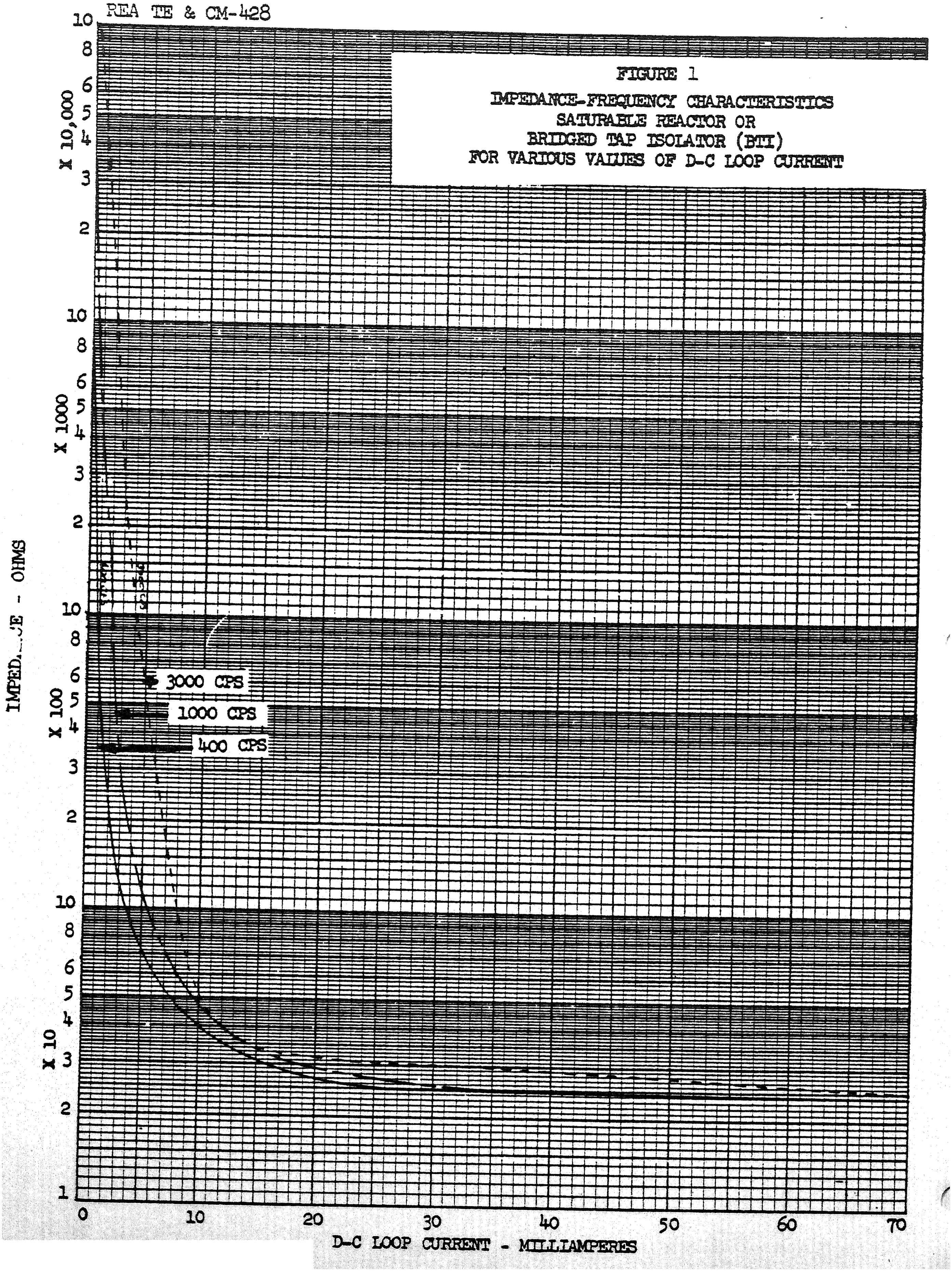


FIGURE 1

IMPEDANCE-FREQUENCY CHARACTERISTICS
SATURABLE REACTOR OR
BRIDGED TAP ISOLATOR (BTI)
FOR VARIOUS VALUES OF D-C LOOP CURRENT

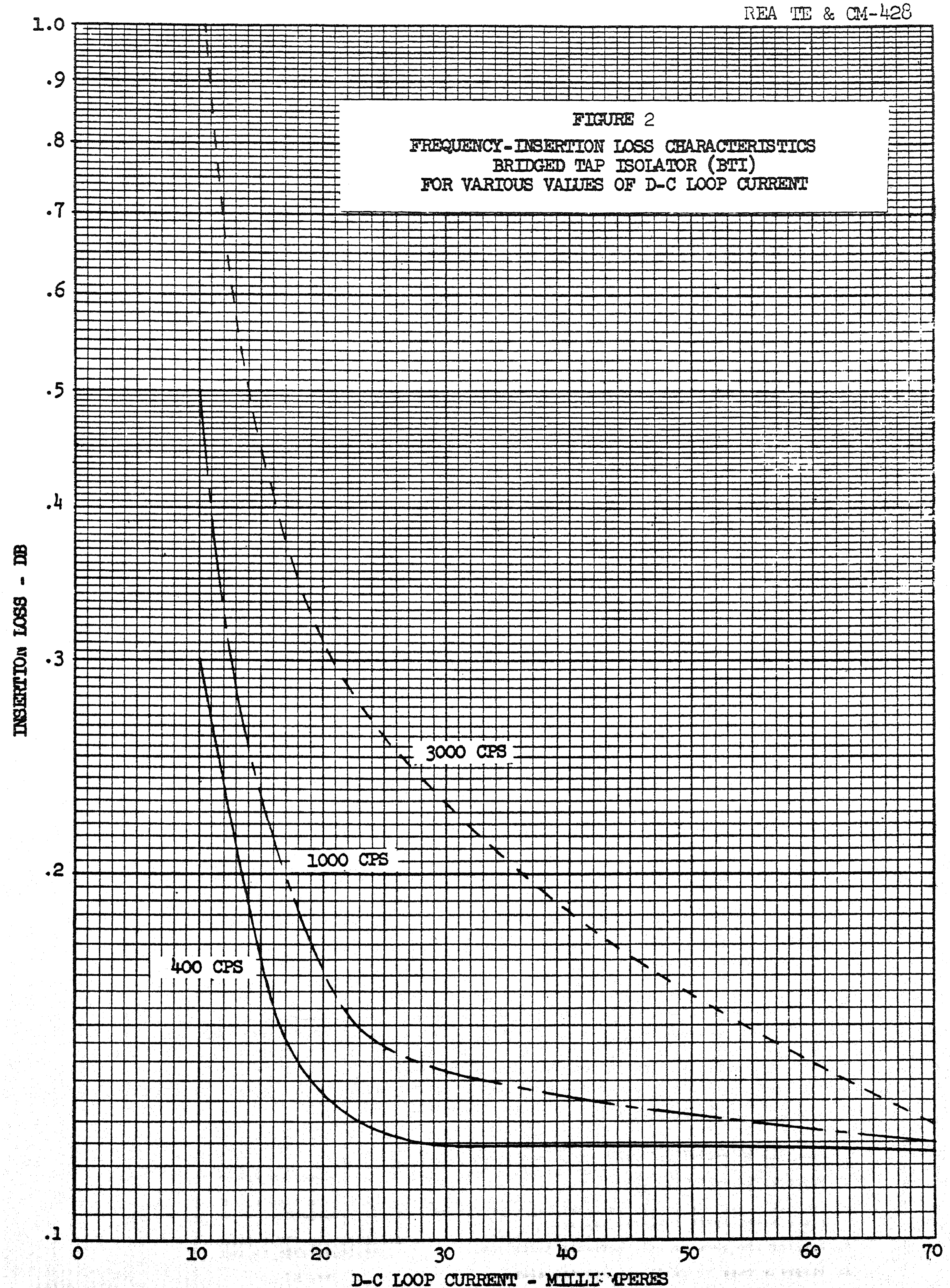
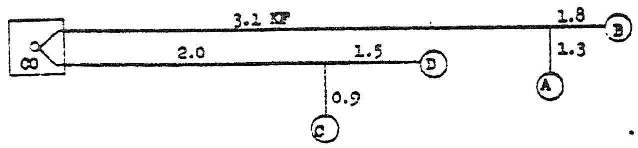


FIGURE 2
FREQUENCY-INSERTION LOSS CHARACTERISTICS
BRIDGED TAP ISOLATOR (BTI)
FOR VARIOUS VALUES OF D-C LOOP CURRENT
3000 CPS
1000 CPS
400 CPS
INSERTIOn LOSS - DB
D-C LOOP CURRENT - MILLIAMPERES
1.0
.9
.8
.7
.6
.5
.4
.3
.2
.1
0
10
20
30
40
50
60
70

ILLUSTRATIVE EXAMPLE 1 To show how to treat a loop similar to the one shown below.



REFERENCE — Section 428

PROCEDURE

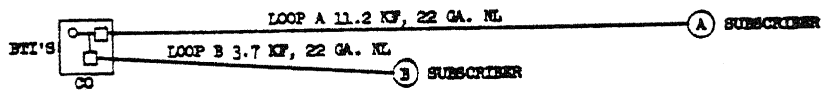
1. The amount of bridged tap to each subscriber is:

Subs. "A"	Subs. "B"	Subs. "C"	Subs. "D"
1.8	1.3	1.5	0.9
2.0	2.0	3.1	3.1
1.5	1.5	1.8	1.8
0.9	0.9	1.3	1.3
6.2 kf	5.7 kf	7.7 kf	6.1 kf

2. This is less than 9 kf. Therefore, the two pairs can be connected at the central office mainframe without bridged tap isolators. — Par. 3.9

3. Each loop also meets its own transmission requirements for bridged taps. — Par. 3.1

ILLUSTRATIVE EXAMPLE 2 To show how to treat a loop similar to the one shown below.



REFERENCE — Section 428

PROCEDURE

1. The bridged tap length to loop "B" subscriber "B" when loop "A" is un-isolated is: 11.2 kf

2. This is greater than 9 kf. Therefore, bridged tap isolators are used in each loop at the central office mainframe. — Par. 3.9

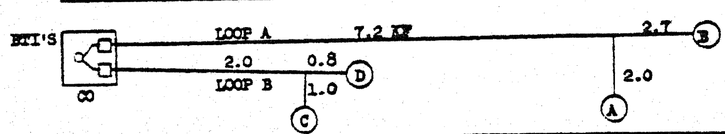
3. Check for d.c. loop current split. The d.c. loop resistance of
   loop "A" is: 11.2 kf x 32.39 ohm/kf = 352 ohms
   loop "B" is: 3.7 kf x 32.39 ohm/kf = 120 ohms

4. For these values of d.c. loop resistance, loop current to each loop will be adequate to saturate reactors. — Table I, Par. 3.1

5. Each loop also meets its own transmission requirements.

6. Ringers in loops "A" and "B" are connected bridged. — Par. 3.7

ILLUSTRATIVE EXAMPLE 3 To show how to treat a loop similar to the one shown below.



Both Loops 22 GA. NL

REFERENCE — Section 428

PROCEDURE

1. The bridged tap length to loop "B" when loop "A" is un-isolated is at least 11.9 kf.

2. This is greater than 9 kf. Therefore, bridged tap isolators are used at the central office mainframe. — Par. 3.9

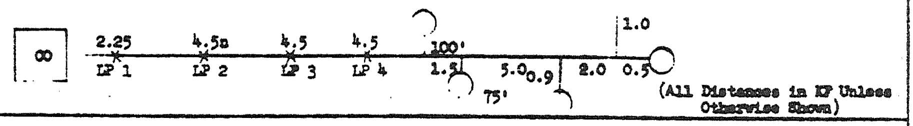
3. Check for d.c. loop current split. The maximum d.c. loop resistance of loop "A" is: 9.9 kf x 32.39 ohm/kf = 320 ohms
   The minimum d.c. loop resistance of loop "B" is: 2.8 kf x 32.39 ohm/kf = 91 ohms

4. For these values of d.c. loop resistance, loop current to each loop will be adequate to saturate reactors. — Table I

5. Each loop also meets its own transmission requirements. — Par. 3.1

6. Ringers in loops "A" and "B" are connected bridged. — Par. 3.7

ILLUSTRATIVE EXAMPLE 4   To show how to treat a loop similar to the one shown below.



(All Distances in KF Unless Otherwise Shown)

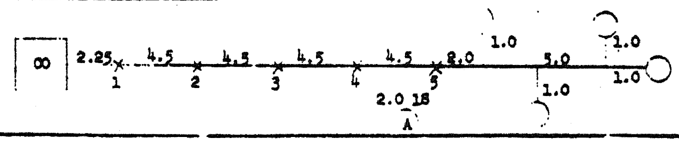
PROCEDURE

REFERENCE

1. The total length of the loop including all bridged taps is:
   (2.25 + 4.5 x 3) + (1.5 + 5.0 + 0.9 + 2.0 + 1.0 + 0.5) = 26.7 kf
2. This is longer than 18 kf. Therefore, D-66 loading is used.
3. The total length of the line after the last loading point is:
   1.5 + 5.0 + 0.9 + 2.0 + 1.0 + 0.5 = 10.9 kf — Section 424 Par. 2.41
4. This is less than 12 kf. Therefore, no bridged tap isolators are necessary and the end-section requirement is met. — Section 424 Par. 4.03

Note: "X" indicates load point.

ILLUSTRATIVE EXAMPLE 5   To show how to treat a loop similar to the one shown below.

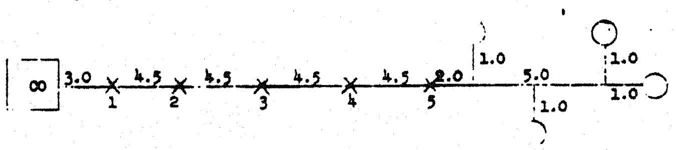


(All Distances in KF)

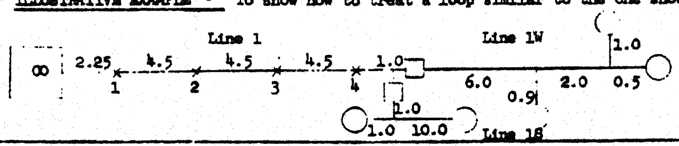
PROCEDURE

REFERENCE

1. The total length of the loop including all bridged taps is over 18 kf. Therefore, D-66 loading is used (4 load points).
2. The total length of line after the last loading point (coil No. 4) is:
   4.5 + 2.0 + 2.0 + 1.0 + 5.0 + 1.0 + 1.0 + 1.0 = 17.5 kf
3. This is over 12 kf so that bridged tap isolators are considered. But bridged tap isolators are not effective, for the particular subscriber distribution of this example, in reducing the end section to 12 kf.
4. Therefore, subscriber "A" (including branch tap 1S) is assigned to a different cable pair. This allows loading point No. 5 to be placed in the line.
5. The total length of line after the last loading point (coil No. 5) now is: 2.0 + 1.0 + 5.0 + 1.0 + 1.0 + 1.0 = 11 kf
6. This is less than 12 kf. Therefore, no bridged tap isolators are required and the end-section requirement is met. — Section 424 Par. 403
7. The final loop layout is shown in the figure below:



ILLUSTRATIVE EXAMPLE 6   To show how to treat a loop similar to the one shown below.



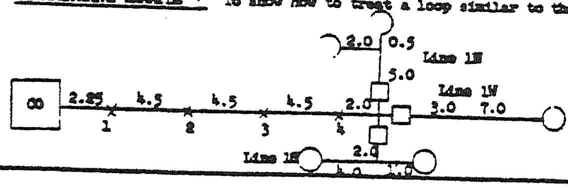
(All Distances in KF)

PROCEDURE

REFERENCE

1. The total length of the loop including all bridged taps is longer than 18 kf. Therefore, D-66 loading is used. — Section 424 Par. 2.41
2. The total length of line after the last loading point is:
   1.0 + (1.0 + 1.0 + 10.0) + 6.0 + 0.9 + 2.0 + 1.0 + 0.5) = 23.4 kf
3. This is longer than 12 kf. Therefore, bridged tap isolators are used as shown above. — Section 424 Par. 4.04
4. The placement of the bridged tap isolators as shown above enables any subscriber on Lines 1S and 1W to meet end-section requirements.
5. Since bridged tap isolators are used, all ringers in the entire loop are connected bridged.

ILLUSTRATIVE EXAMPLE 7 To show how to treat a loop similar to the one shown below.



(All Distances in KF)

PROCEDURE | **REFERENCE**

1. The total length of the loop including all bridged taps is over 18 kf. Therefore, loading is used.

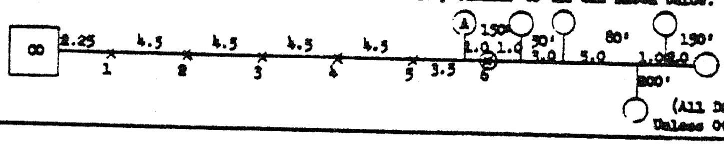
2. The total length of the line after the <u>last</u> loading point is: 2.0 + (5.0 + 0.5 + 2.0) + 10.0 + (2.0 + 1.0 + 4.0) = 26.5 kf

3. This is longer than 12 kf. Therefore, bridged tap isolators are used as shown above. — Section 424, Par. 4.04

4. The placement of bridged tap isolators as shown above enables any subscriber on Lines 1S, 1W and 1N to meet end-section requirements.

5. <u>Since bridged tap isolators are used all ringers in the entire loop are connected bridged.</u>

ILLUSTRATIVE EXAMPLE 8 To show how to treat a loop similar to the one shown below.



(All Distances in KF Unless Otherwise Shown)

PROCEDURE | **REFERENCE** Section 428

1. The total length of the loop is over 18 kf. Therefore, loading is used as shown above.

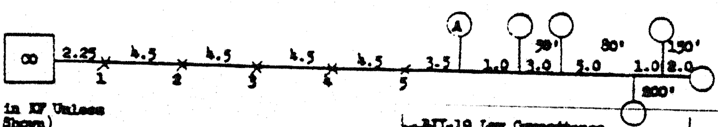
2. The total length of the line (drops are neglected) after the <u>last</u> loading point (coil No. 5) is: 3.5 + 1.0 + 1.0 + 3.0 + 5.0 + 1.0 + 2.0 = 16.5 kf

3. This is longer than 12 kf. Therefore, bridged tap isolators should be used. The particular subscriber distribution in this loop, however, <u>cannot</u> be dealt with by the use of reactors. — Section 424, Par. 4.04

4. Therefore, load point No. 6 is added (shown in circle in figure above). Since this would place subscriber "A" between load points, subscriber "A" is (a) assigned to a different cable pair, or (b) low capacitance 19-gauge wire is used beyond load point No. 5. The correct configuration using the low capacitance wire is shown in the figure below.

5. The total effective end-section length of line <u>after</u> the last loading point now is: (3.5 + 1.0 + 1.0 + 3.0 + 5.0 + 1.0 + 2.0)/2 = 8.25 kf

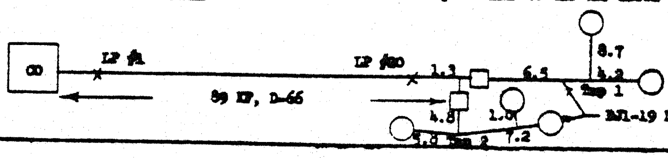
6. This is less than 12 kf and it meets the requirements



(All Distances in KF Unless Otherwise Shown)

BJT-19 Low Capacitance

ILLUSTRATIVE EXAMPLE 9 To show how to treat a loop similar to the one shown below.



BJT-19 Low Capacitance Wires

PROCEDURE | **REFERENCE**

1. The total length of the loop after the last loading point exceeds 12 kf.

   Length of tap 1 is: 1.3 + (6.5 + 4.2 + 8.7) = 20.7 KF

   Length of tap 2 is: 1.3 + (4.8 + 6.2 + 1.0 + 5.8) = 19.1 KF

2. Because the length of <u>each</u> tap is longer than 12 kf, <u>both</u> bridged tap isolators and low capacitance wire are required. This is shown in the figure above. — Section 424, Par. 4.04

3. Using the BJT-19 low capacitance wire the effective bridged tap length is:

   Tap 1: 1.3 (6.5 + 4.2 +8.7)/2 = 11.0 KF

   Tap 2: 1.3 + (4.8 + 6.2 + 1.0 + 5.8)/2 = 10.2 kf

This meets the end-section requirements.